DOCUMENT RESUME

ED 179 805 CE 023 577

AUTHOR McCormick, B. G.: McCormick, Robert S.
TITLE A Study of Interior Wiring, Color Coding, and Switching Principles by Simulation and Practice.
INSTITUTION Technical Instruction Systems, Springfield, Ill.
PUB DATE 80
NOTE 55p.

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Electrical Systems: *Electric Circuits: Electricians: *Electricity: Safety: Simulation: Textbooks: Vocational Education

ABSTRACT

After a preliminary introduction and a chapter on wiring and electricity safety procedures, this study text proceeds to offer a general coverage of single and polyphase alternating current electrical systems used to power factories, farms, small businesses, and homes. Electrical power, from its generation to its application, is discussed, with the greatest emphasis in the text placed upon helping students to learn to construct, control, and color code interior wiring circuits through low voltage simulation exercises and application of basic principles. Practical switching arrangements are diagrammed, and the differences between parallel and series circuits are explained. The text contains a recommended reading list, procedures for carrying out an electrical needs assessment, an order sheet, a guide to symbols used, and an appliance consumption rating chart. (CP)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED179805

CE

A STUDY OF INTERIOR WIRING, COLOR CODING, AND SWITCHING PRINCIPLES BY SIMULATION AND PRACTICE

U S DEPARTMENT OF HEALTH
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

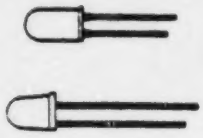
"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

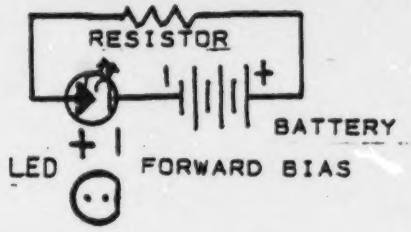
Robert McCormick

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

CE023507

COPYRIGHT © 1980
TECHNICAL INSTRUCTION SYSTEMS, P.O. BOX 4402, SPFLD., ILL 62708
B.G. & R.S. McCORMICK, AUTHORS + PUBLISHERS
ALL RIGHTS RESERVED





These are light emitting diodes (LEDS), the heart of the functional DC simulator you are about to use. Here is a base diagram of a LED and a circuit with a LED forward biased. The flat side carries the cathode or negative terminal, while the round side carries the anode or positive terminal. The positive terminal when connected to the positive terminal of a cell, and the cathode to the negative terminal, constitutes forward bias--conductance takes place and the LED glows! The anode of the LEDS used in the simulator are always connected to the gold or brass (HOT) terminal of duplex outlets or lampholders to observe polarity. The commutation switch S-4, in the power supply reverses the polarity on the outside supply leg as does AC current on a transformer. This arrangement supplies forward bias (positive charge) to the anode to LEDS placed on one side of the breaker panel branch circuits. When the commutation switch is changed the other side works. The student will know when he has done his work correctly, the LED will glow when forward biased, if not, start looking for the problem. (If a filament transformer is used as the source voltage a rectifier is necessary to provide the same effect.)

LEDS react to the voltage-current relationship the same as most junction diodes, the current rises rapidly once forward conductance starts and rises rapidly with no appreciable rise in voltage. It is therefore imperative the current be limited by a series resistor or the LED is destroyed by heat. A simple formula follows used to calculate the series resistor needed to control the current at a safe level. (Safe level in this instance means approximately 20 Ma. so as not to create heat in the LED.) Vin voltage to operate LED, Vled the LED forward voltage, I specified operating current. $R_s = \frac{Vin-VLED}{I}$

By carefully inserting wire-wrap pins in the magnetic base units, as illustrated, breaker and/or branch circuit panels, duplex outlets, switched outlets, single-pole switches, three-way switches, four-way switches, and combinations of switches and lampholders may be assembled. From these units, circuits are constructed. By observing the polarity of the LEDS placed in the circuits, the user will master the electrical principles of interior wiring. Through further application of the simulator, selection and routing of cables may be learned as well as color coding of the circuits constructed. Circuit analysis and power consumption principles may then be studied to enhance the learning process.

The skills necessary to do actual home wiring take little time to learn once the principles of interior wiring have been mastered. Under NO circumstances is the person using this simulator to assume he can or should or has the skill and ability to open electrical equipment, construct circuits, or get involved with domestic AC circuits as the result of having constructed and understood the simulator exercises. Have a professional, or apprentice yourself to a professional to learn the skills part of electrical science. Study at a trade school, adult evening school, or as a technician or engineering student to complete your training. Observing safety and exercising safe practices with electricity is not to be taken lightly--it's a matter of life and death!

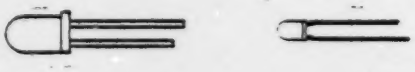
THE CURRENT THROUGH A LED MUST BE LIMITED, OR HEAT DESTROYS IT. A SERIES RESISTOR IS USED TO LIMIT CURRENT. THIS FORMULA IS USED TO DETERMINE THE SERIES RESISTOR.

WHERE V IN IS THE VOLTAGE AVAILABLE TO OPERATE THE LED

V LED IS THE LED FORWARD VOLTAGE

I IS THE DESIRED OPERATING CURRENT

$$R_S = \frac{V_{IN} - V_{LED}}{I}$$



LED PROFILES
CATHODE NEG. -
ANODE POS. +

The basic building blocks of the simulator is of course the magnetic units. From the magnetic units, the breaker panel, outlets, junction boxes, switches, lampholders, and appliance anchor points are made. By carefully constructing each piece as illustrated, and in the relative numbers as called for, maximum utility of your simulator can be achieved. Wire-wrap pins should not be removed once set as the magnetic base units are damaged each time. Set the pins carefully, as vertically as possible, once set, a poor or sloppy job will remain. (Never insert pins in cold bases, the pins will bend over. Warm base material in warm water, do not boil or incinerate.) An easy way to mark or identify polarized wire-wrap terminals is to paint a dot on the magnetic base with "white-out" liquid paper, a typist's supply. This same product is also used to color code conductors. Do not confuse color coding conductors with identifying polarity of terminals, they are related but not identical. Once the polarity identification and color coding paint has served its purpose, it may easily be chipped off and the base or conductor reused. White-neutral, Black-hot, Red-hot switched lead, Blue-hot switched lead, Green-ground only. (You may also use 1, 2, or 3 dots of white as a color code.) Colored insulated wire may be supplied with some units.

The breaker panel is made of several magnetic units ganged together, a dot represents a pin. All the stabbed holes in the magnetic units may not be filled with pins. The additional holes are for three-phase simulation, an optional study. If branch circuit saturation is achieved and more circuits are needed, then all the pins may be installed and used for 110V and 220V single-phase simulation.

The duplex outlet terminal is a versatile base, it may serve as a breaker panel unit, a lampholder, a split switched outlet, a switched outlet, a combination switch and outlet, single-pole switch, three-way switch, four-way (commutation switch), double-pole single throw switch or

about anything you want it to be. An additional pin may be added in some cases to accommodate a neutral or ground wire terminal connection. The base also has three-phase applications as previously stated.

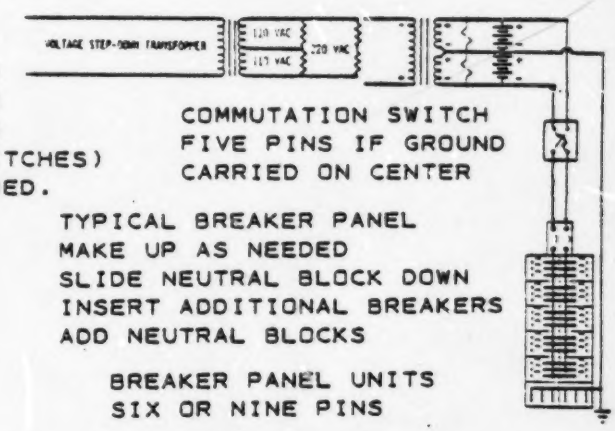
Use the wire-wrap and pin insertion tool as follows:

Wire-wrap tools without spools and wire running down through the inside from the top should have the insulation stripped by fine sand paper. The end is then pushed up through the hole in the wrap tool about one-quarter inch, then inserted over the pin and wrapped, wire tip disappears, PRESTO! a connection.

100 MAGNETIC BASES SHOULD YIELD APPROXIMATELY:

- 15-9 PIN BASES (BREAKER BASES)
- 40-5 PIN BASES (DUPLEX OUTLETS)
- 10-5 PIN BASES (4-WAY SWITCHES)
- 15-4 PIN BASES (3-WAY SWITCHES)
- 20-3 PIN BASES (SINGLE-POLE SWITCHES)

INSERT PINS IN BASES ONLY AS NEEDED.



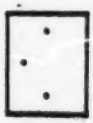
COMMUTATION SWITCH
FIVE PINS IF GROUND
CARRIED ON CENTER

TYPICAL BREAKER PANEL
MAKE UP AS NEEDED
SLIDE NEUTRAL BLOCK DOWN
INSERT ADDITIONAL BREAKERS
ADD NEUTRAL BLOCKS

BREAKER PANEL UNITS
SIX OR NINE PINS

INSERT PINS IN
WIRE-WRAP TOOL
PUSH PINS INTO
WARM BASES AS
SHOWN IN DIAGRAM

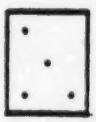
S_1 THREE PINS



CENTER PIN
MAY CARRY
GROUND,
SWITCH LEG,
NEUTRAL.

S_1

S_3 FOUR PINS



CENTER PIN
MAY CARRY
GROUND,
SWITCH LEG,
NEUTRAL.

S_3

S_4 FIVE PINS

S_4

SWITCH LEG TERMINALS
BRASS OR GOLD COLOR
MARK WITH PAINT (HOT)

DUPLEX OUTLET
FIVE PINS

DUPLEX OUTLET (HOT)
OUTSIDE LEG TERMINAL
MARK WITH PAINT

BASES GANGED END TO
END PRODUCE DOUBLE
TERMINAL CONTACTS &
REDUCE SPACE NEEDED.

PREFACE

Electrical power has proven to be one of the most useful tools ever conceived by the human mind. The uses to which it may be put have not been exhausted, and its uses continue to grow in the home, factory, farm, transportation, communications, and in the compilation of data information.

As a result of the increased sophistication of devices using electrical power and the theory covering such devices, the emphasis on instruction in the classroom has changed. This shift in instructional emphasis has placed great importance on the electronic segments of electrical science, especially at the complex end. The same may be said about the educational aspects of training in the use of domestic applications. In addition to teaching present technological advances, it is a concern that elementary generating, transmission, transforming, and applications of electrical power remain a mystery to many young people and to adults as well. In fact, many people never have the opportunity to learn about the electrical service to their own home. This fact, probably more than any other reason, is the greatest impediment standing in the way of a desire to understand the deeper and more complex techniques used in communications circuits, data circuits, and the thousands of other devices used in our modern world.

Acquiring a basic knowledge of the electrical power industry transmission and distribution systems, along with service and branch circuit systems, might be a point at which an active interest in electricity could be developed. Part of the problem, it seems, centers around the mystery of functional parts of electrical service systems as a result of being enclosed and hidden from view. In addition, written

and easy to follow schematic descriptions of electrical systems are usually disjointed and difficult to understand. At times, drawing of a function is not enough to give a person full grasp of the situation, but viewing and assembling some working units is quite meaningful.

By using a simple direct current simulation system, powered by simple flashlight cells, a few light emitting diodes (LEDS), some magnetic anchors and a piece of sheet metal, a floor plan, a few wire-wrap pins, and a little #28 or #30 gauge color coded wire, the entire home electrical system can be duplicated.

In addition, through simulation, dangerous line voltages are never required or encountered. (LINE VOLTAGES SHOULD NOT BE USED WITH THIS SYSTEM.) If a center tapped filament transformer is used to reduce the line voltage and to isolate the line from the instructional unit, it should be U. L. approved and under the supervision of an expert. Secondary voltages of 2.5, 5, 6.3, 10, 12.6VAC delivering center tapped voltages of half that amount may be used to match the LEDS used. 1.5 Volt or 5 Volt LEDS with current limiting resistors are used.

The student is forewarned that to open an outlet, switch, lampholder, or breaker panel (branch circuit panel) at this, or anytime, without professional supervision, is a dangerous and foolish act and a poor way to "learn" about electricity.

This introduction to practical home or consumer electricity is not meant to be an exhaustive study of either basic electricity or of interior wiring. Indeed, it is the intent to introduce students to the subject of electricity on the premise they will become interested enough to read and learn more from additional sources. A list of titles and authors may be found in the appendix. These titles may be found in a library or purchased as desired from Technical Instruction Systems, P.O. 4402, Springfield, Illinois 62708.

INTRODUCTION

This booklet was written and illustrated to acquaint the reader with the basic principles of an operational commercial electrical system, especially as the transmission, distribution, service and branch circuit network services our homes. The text will move rapidly through the generating, transforming, transmission, and commercial applications of electrical energy. The reader, as a result, should feel informed on "how" the power gets to farms, factories, and homes.

Once the power "arrives" at the home distribution or branch circuit panel, the text information will become more specific and directed to the title of the manuscript, A STUDY OF INTERIOR WIRING, COLOR CODING, AND SWITCHING PRINCIPLES BY SIMULATION AND PRACTICE.

The reader should be made aware this is not an engineering text; however, engineering electrical theory is applied which states, "that a body is raised to a pos. (+) charge by the source voltage or EMF, and passes to a state of neg. (-) charge in passing through a load resistor. This is known as the "current theory" as opposed to the "electron theory" of electricity. Neither is this text a guide to practice as an electrician. This text is a guide to help toward understanding the principles of interior wiring through simulation exercises.

To practice as an electrician, one should learn the trade as an apprentice under the tutoring of a journeyman electrician. Under NO circumstances should the student attempt to construct or service any power line(s) or equipment in the home or elsewhere.

When using the battery powered simulator, all exercises are low voltage and are completely safe, if safe practices are followed.

If, after having read the text and used the simulator equipment, the student feels enthused about learning more about the art and science of electricity, he should read and study further. The titles of many fine books for all ages and stages of academic interests and development appear in suggested reading in the appendix. Books in Print Index is an excellent source of book titles. Have a professional librarian help you locate suitable book titles for your needs.

The student is directed to read the safety section which follows:

SAFETY FIRST

Acquiring good safety habits is a lifelong process. Failure to develop good safety habits, of course, can terminate the life process. The wiring simulator you are about to use has been designed to be electrically harmless. THE STUDENT IS WARNED TO USE ONLY THE BATTERY PACK PROVIDED AND NOT TO USE LINE VOLTAGES OF 110 VOLTS OR MORE WITH ANY OF THE EQUIPMENT. In addition, hook-up wire, wire-wrap pins, insertion tools, or any of the accessories are not to be thrown, shot, or driven into oneself or others. There is always a danger of eye damage or other bodily harm done by wires or projectiles. Report all injuries to your instructor or an adult.

If the student or instructor decides to use a center-tapped filament isolation transformer as a power source with the simulator, the transformer primary should be plugged into a Ground Fault Interrupter (GFI). This should be done after the GFI is plugged into the wall outlet (110 V only). The center-tapped filament transformer should be U.L. approved and should not exceed 12.6 VAC output from the secondary winding. Being a center-tapped secondary could provide a range of secondary voltages from 1.5-6.3 VAC respectively for matching the operating voltages of the LEDS enclosed. (NOTE: To be able to observe polarity visually using an AC transformer, a rectifier--half or full--wave must be inserted correctly into the secondary supply circuit.) The D cell pack provided with the simulator supplies either 1.5, 3, or 4.5 VDC and is not hazardous.

There are a multitude of DO's and DON'Ts involved in electrical safety just as there are in driving a car. There are two major differences with electricity--you can't see

it, and it is faster, it moves at the speed of light (186,000 miles per second). The effect of electric shock is a jarring sensation. Shock hazard is incurred at a potential (voltage) level of 48 to 52 volts AC, 25-30 volts AC are considered the safe limits. Unfortunately, the 60 Hertz (cycle) current in use is a frequency to which our internal organs, and voluntary and involuntary nervous systems are susceptible. One milliampere of current (1 Ma) is known to cause shock, 25 Ma has been known to be fatal, 50 Ma is considered to be extremely dangerous, and 100 Ma is lethal in all instances at 60 cycles. The amount of current drawn through the organs or body is dependent on several factors. Frequency of the current, voltage present, resistance of the skin, how well grounded the person is, the path the current takes in traveling through the body. All these factors play a part in determining the intensity of the current. If a person allows himself to become a conductor in a circuit through ignorance, foolishness, carelessness, a mistake or otherwise, it makes no difference, electricity is unforgiving. If an electrical shock causes the heart muscle to fibrillate (race out of control, in which case it pumps little blood) the victim dies of suffocation. Action through some means is required to restore regular heart frequency. CPR (cardiopulmonary resuscitation) artificial respiration should be learned so it may be employed in use with shock victims. Resuscitation should be continued until a physician arrives.

The following statements may serve as guidelines for improved safety practices. Add your own ideas to this list of safety precautions.

Never tamper with any electrical equipment until YOU are satisfied it is not "live," and that you are aware of its condition.

Always switch the main breaker to the off position to disconnect the service lines from the branch circuits before work proceeds on any circuit. If possible, lock off the main breaker.

If there is any doubt about difficulties in circuits involving service lines, meters, main breaker, call the power company, they will be happy to disconnect their service until the problem has been corrected by a professional. As a novice, don't get involved in home circuit construction or troubleshooting, call a professional.

In addition to the above general guidelines, there are specific topics that should be explored and discussed.

Disconnecting inductive loads, motors requiring fast circuit interruption.

Disconnecting capacitive loads, or capacitive isolated loads, shorting and dumping the standing capacitance of unplugged appliances.

Observance of polarity when keyed or polarized plugs are used or called for in place of isolation transformers.

Discuss the installation, function, and purpose of GFI (Ground Fault Interrupters).

Explore all aspects of grounding. Discuss the problems of using ungrounded equipment, especially as it relates to portable tools that may be used in metal buildings, in the yard or on damp surfaces, anywhere!

Always use grounded electrical power tools.

Never use over-size fuses or pennies behind fuses.

Always use insulated tools.

Never assume that circuits have but one source of power, even if the master panel has been locked off. Test all load centers, branch and control circuits before entering for repair.

Never remove the neutral (white) wire from an electrical system until you have checked and made certain the power has been locked off and tests have been made to confirm there is no current. (By removing the neutral from a circuit, the technician places himself in series with ground. Any and all current drawn by the parallel up-stream appliances go to ground through him if he is grounded in any way.)

When working with electrical equipment or appliances, even though the power has been locked off, develop the habit of using ONLY ONE HAND to work on or touch any one appliance, load center, or instrument at one time. Jarring shocks can be inflicted by touching two instruments at the same time.

Do not expose yourself to live conductors, connectors, or other hazards through failure to close electrical cabinet doors. Use protective clothing and wear rubber gloves when advisable.

Never work on electrical equipment of any sort (high or low voltage) where explosive gases or fumes are present or suspected (includes containers formerly used for fuel storage). (This applies to the simulation trainer.)

Never put water or carbon tetrachloride on an electrical fire. Carbon tetrachloride when heated forms deadly phosgene gas. Use only carbon dioxide or other approved extinguishers.

Never touch a down wire. Report any such occurrence to an authority, especially the police.

Never wear loose, flopping clothing with zipper or metal buttons, or shoes having nails in them when doing electrical work.

Never use metal ladders around any electrical power lines of any voltage.

If installing TV antennas or other metal masts, check to see there are no power lines in case the mast should fall and come in contact. Many persons are electrocuted in this manner.

Always check and make sure it is safe to energize a circuit.

Continue to learn safety practices from others, be critical!

It has already been mentioned that the simulator equipment and exercises are perfectly safe; however, the student should view each exercise in light of the safety

practices he or she would need to observe if the same activities were performed on an industrial or domestic electrical circuit. Make it a habit to think--SAFETY!

Discuss safety practices, considerations, features, possible mistakes, or freak errors that might occur in real situations. Classmates and instructors should prove helpful in the discovery of better safety habits.

Start your own list of safety practices here--

The purpose of this text is to acquaint the reader with single and polyphase (usually 3-phase) alternating current electrical systems used to power factories, farms, small businesses, and homes. To achieve this goal, the reader will be introduced first to an overall but simplified view of a commercial power generating and distribution system as it might exist. Once the electrical system has been developed to the point of bringing the service into the home, the goal will be to have the student begin to duplicate and simulate the circuits through the use of basic building units and exercises. Architectural floor plans will be presented in which the procedures of decision making for circuit design are initiated. These circuits will be D.C. powered low voltage simulations of resistive loads only and are perfectly safe; however, they carry the same instructional value concerning construction procedure, load protection, grounding, switching, color coding and many other interesting features concerning interior wiring. Direct current theory of electricity will be used exclusively to introduce the simulation exercises. User adaptations to low voltage single and polyphase systems are welcomed, and will become the subject of a simulation user newsletter. Please send corrections or recommendations you have for improved understanding and use of the simulator to Technical Instruction Systems, P.O. Box 4402, Springfield, Illinois 62708. These suggestions will be passed along to other users through the newsletter under your name. Feature articles are also welcome and if chosen for publication will be printed under your name as author.

If the student is not acquainted with elementary electrical theory, symbols and terms, it would be very beneficial to review that material from an elementary text until

they become totally familiar. All the terms may be found in a regular dictionary. The student should also read basic electrical theory from several other texts as the presentations of other authors fill in voids making abstract concepts much clearer.

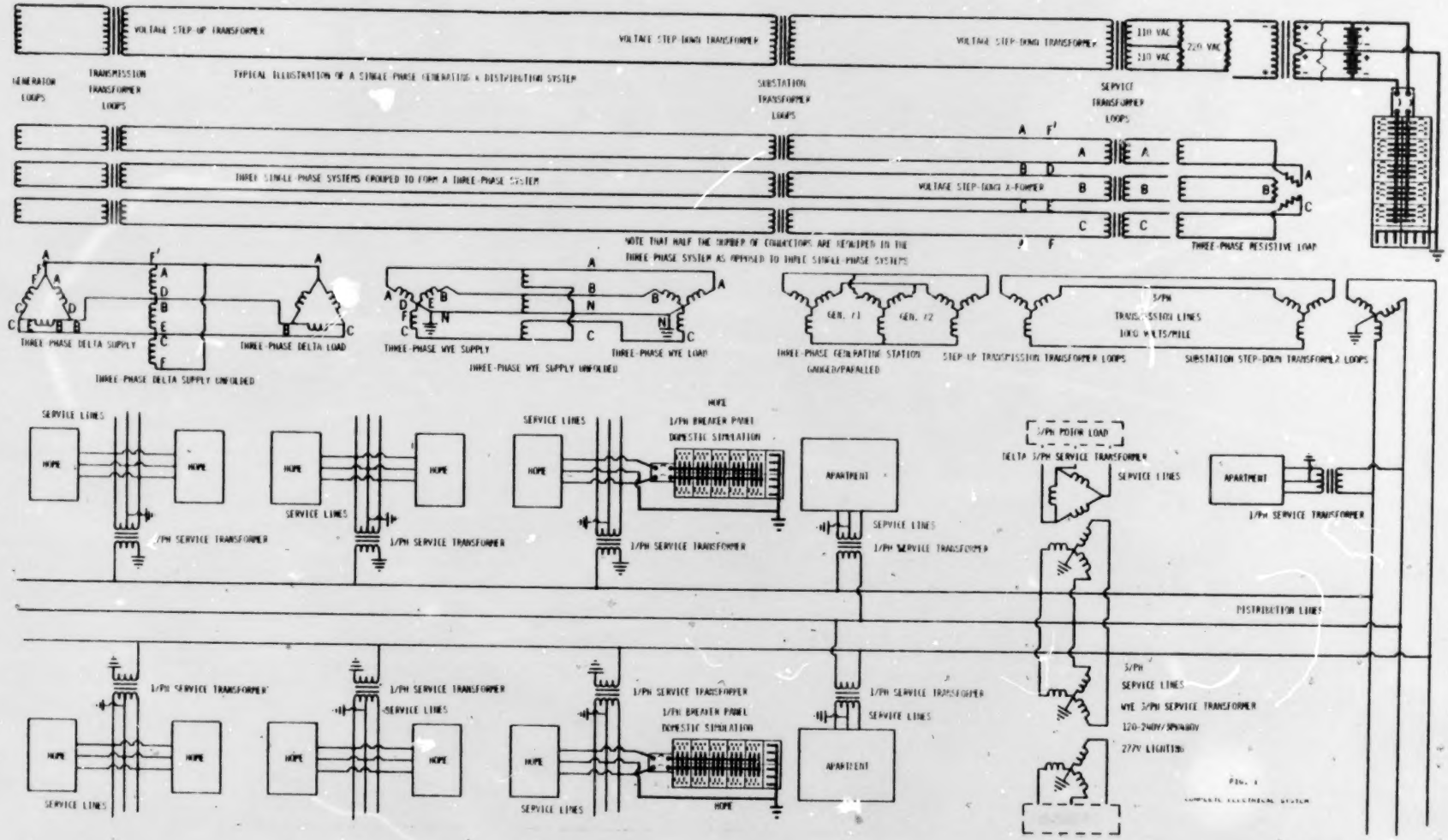
As progress toward the understanding of interior wiring develops, power consumption calculations will be introduced since this is the most sensible way to analyze and calculate the power parameters and consumption of the circuit loads.

The rules and laws relating to series and parallel circuit analysis will be touched upon. An example problem will be included as part of that circuit analysis. To become really proficient at circuit analysis, study texts especially designed with that purpose in mind. There are several listed in suggested readings in the appendix.

Simple rules and procedures for making practical electrical measurements are not included. Electrical measurements is a special subject. Howard Sams Publishers, Indianapolis, has many titles on the subject.

At times it is beneficial to approach a subject by getting a general overall view of things before attempting to describe and understand its specifics. This is the approach which is taken in attempting to understand the monumental and complex power generating, transforming, transmission, distribution, service, and branch circuit systems which make up a modern power network.

A complete electrical system diagram or schematic is graphically portrayed in Fig. 1. This figure shows the modern electrical system down to the distribution panels (branch circuit panel, breaker panel, fuse box, synonomous terms) of the factory, farm, business, or home. (There are many other types of breaker panels in use besides the one shown.)

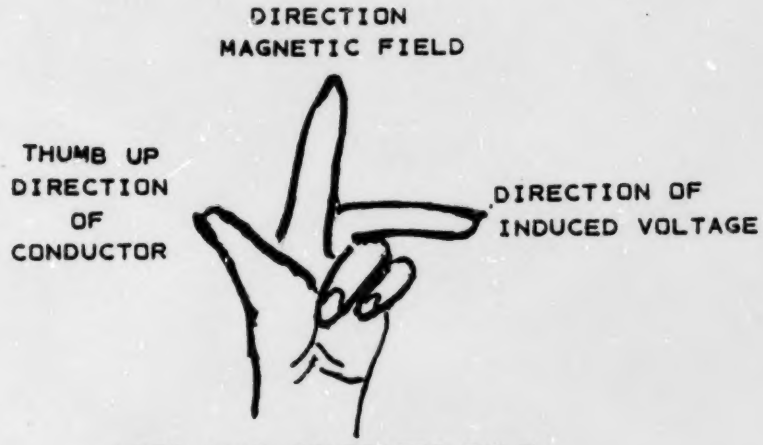

VOLTAGE STEP-UP TRANSFORMER
VOLTAGE STEP-DOWN TRANSFORMER
VOLTAGE STEP-DOWN TRANSFORMER
110 VAC
110 VAC
220 VAC
GENERATOR LOOPS
TRANSMISSION TRANSFORMER LOOPS
TYPICAL ILLUSTRATION OF A SINGLE PHASE GENERATION & DISTRIBUTION SYSTEM
SUBSTATION TRANSFORMER LOOPS
SERVICE TRANSFORMER LOOPS
THREE SINGLE PHASE SYSTEMS GROUPED TO FORM A THREE-PHASE SYSTEM
VOLTAGE STEP-DOWN TRANSFORMER
THREE-PHASE RESISTIVE LOAD
NOTE THAT HALF THE NUMBER OF CONDUCTORS ARE REQUIRED IN THE THREE PHASE SYSTEM AS COMPARED TO THREE SINGLE-PHASE SYSTEMS
THREE PHASE DELTA SUPPLY
THREE PHASE DELTA LOAD
THREE PHASE DELTA SUPPLY UNFOLDED
THREE-PHASE WYE SUPPLY
THREE-PHASE WYE LOAD
THREE-PHASE WYE SUPPLY UNFOLDED
GEN. #1
GEN. #2
THREE-PHASE GENERATING STATION GANGED/PARALLED
3/PH TRANSMISSION LINES 1000 VOLTS/MILE
STEP-UP TRANSMISSION TRANSFORMER LOOPS
SUBSTATION STEP-DOWN TRANSFORMER LOOPS
SERVICE LINES
HOME
1/PH SERVICE TRANSFORMER
1/PH BREAKER PANEL DOMESTIC SIMULATION
APARTMENT
3/PH MOTOR LOAD
DELTA 3/PH SERVICE TRANSFORMER
DISTRIBUTION LINES
3/PH SERVICE LINES
WYE 3/PH SERVICE TRANSFORMER
120-240V/5PHASE
277V LIGHTING

Commercial power is usually generated near large accessible sources of fuel heat supplied by oil, gas, or coal. Atomic reactors may also be used to supply heat. The generating systems must be located near a large body of water which is used to condense steam and to cool the boilers super structure. All of this is usually done as near as possible to the customer. This, however, has grown less important over the years due to improved high-voltage transmission technology. This feature alone enables the transmission of power over long distances without appreciable loss of energy.

The generating plant uses heat energy derived from a reaction or the burning of fuel to convert water to steam in a closed system which in turn drives a turbine. The turbine rotation is coupled mechanically to a dynamo (generator). Most modern power plant dynamos produce three-phase or poly-phase current. All power plants have several of these three-phase dynamos which may be synchronized and ganged in parallel to meet a demand load. In some instances, comparatively small diesel powered dynamos are used to pick up instantaneous small or fluctuating local loads which might be difficult or uneconomical to meet with steam powered dynamos that require long start-up times. They also serve well for local emergency power. They all have one feature in common, they produce three or single-phase, 60 Hertz (cycle) alternating current.

The power is taken off the stationary portion or stator of the dynamo. The rotor or rotating shaft to which the excitation field loops are attached creates a magnetic field in motion which induces an electromotive force (emf) into the wire loops of the stator. This satisfies the relationship for inducing a current flow in a conductor, namely, (a moving conductor, or a magnetic field moving through a conductor or collapsing around a conductor, these circumstances or any one of them induces or causes a current to flow). Fig. 2. The rate at which the magnetic field

is rotated in the presence of the load loop determines the frequency of the current generated.



LEFT HAND GENERATOR RULE
GENERATING AN EMF IN A CONDUCTOR

FIG. 2

When a conductor is moved upward at right angles with a field force moving away, an electron flow is induced toward the right in the conductor. This phenomena may be demonstrated using the LEFT-HAND GENERATOR RULE, which states: With the thumb, first, and second fingers of the left hand extended at right angles to one another, the index finger pointing in the same direction as the magnetic field, the thumb in the direction of the conductor's motion, the second finger then indicates the direction of current flow in the conductor. If a load is connected to the conductor, electron flow will improve and the resistance to the movement of the conductor will be enhanced requiring more force to move the conductor. The induced current in the conductor will then as a result of the collapsing magnetic field establish a counter emf to oppose the establishment of the primary emf.

The characteristics which govern the intensity of the induced emf follow:

Strength of the magnetic field.

Velocity by which the conductor cuts the magnetic field.

The number of turns of wire making up the generator loops.

In some instances the power is taken directly to the customer (if a large user and close enough) at a voltage potential varying between 12,000 and 24,000 volts or more. If the customer is at some distance from the power plant, the voltage is raised by a (three-phase) step-up transformer. In this process a current intensity trade-off is made through the transformer by introducing a large number of transformer secondary windings which enables magnetic coupling so that the voltage is raised while the current is reduced. The total energy is affected little, P=IxE. The transformation of current to voltage reduces large current and thereby power losses moving over conductors $P=I^2R$. Where P= power in watts, I= current in amperes squared (times itself), R= resistance in Ohms.

Ideally, the transmission voltage level should be approximately 1,000 volts/mile. If the transmission lines should stretch for 500 miles to a distant city, the voltage might possibly be as high as 500,000 volts. Transmission designs presently are at 1,000,000 volts or more.

Once the power is generated, the voltage is raised instantaneously for transmission. Effectively, current distribution and use takes place simultaneously with generation. By raising the voltage, several benefits are reaped. Fig. 3. Transformer coupling. First, the size of the transmission conductor is appreciably reduced; thereby, its weight and cost. With cable weight reduced, the suspension towers strength may be reduced with appreciable savings. In addition, the real savings comes about through by reduction of conductor resistance energy losses $P=I^2R$. By reducing current intensity, that is, raising the voltage through transformer action, energy losses are minimized

for transmission. (Returning to Fig. 1) Substation step-down transformers allow the tapping off of any combination of power needed for distribution while maintaining the efficiency of a high voltage transmission line and a large generating facility. To achieve transformer coupling or magnetic coupling of two loops of conductors, one called the primary the other the secondary, several things must happen.

TRANSFORMER COUPLING

FIG. 3

With the source producing an alternating emf a current will flow in the primary winding exhibiting a rising and falling magnetic field around itself and the secondary winding. If the secondary winding has a load resistor attached, energy will be coupled according to the left hand generator rule. In addition, the greater the load the greater the coupling due to a reduced counter emf in the primary resulting in greater primary current, resulting in a greater magnetic field. There is a limit to this action called saturation and efficiency begins to drop.

The distribution voltages applied to the circuits coming from these substations may range between 2,400 and 18,000 volts. The voltage of the distribution circuit again is determined by the length of the circuit and the end users type and total load demand. This again is a design problem for the power company and is beyond the scope of this booklet. There are, however, some standard design parameters which may be altered as demands change.

Each customer along the distribution circuit is serviced by another or group of step-down transformers.

These transformers in turn service the types of load demands with the proper voltage and type of current for which the equipment or load was designed. If the customer is in a locality where the power company cannot provide some types and levels of current, different electrical equipment must be selected for use. Business and industrial customers who use large electric motors and other systems requiring large efficient and powerful applications of service will require three-phase current. (208-3Ph., 220-3Ph., 440-3Ph., 880-3Ph. VAC RMS) 277 VAC single-phase is also possible for long run load demands and good efficiency. In residential areas where households are close together and load demands are not high, one would expect the service transformer to be single-phase and serve one, two, or three customers. An electric watt hour meter would be attached to each customer's service drop to monitor current flow. Fig. 4 and Fig. 5.

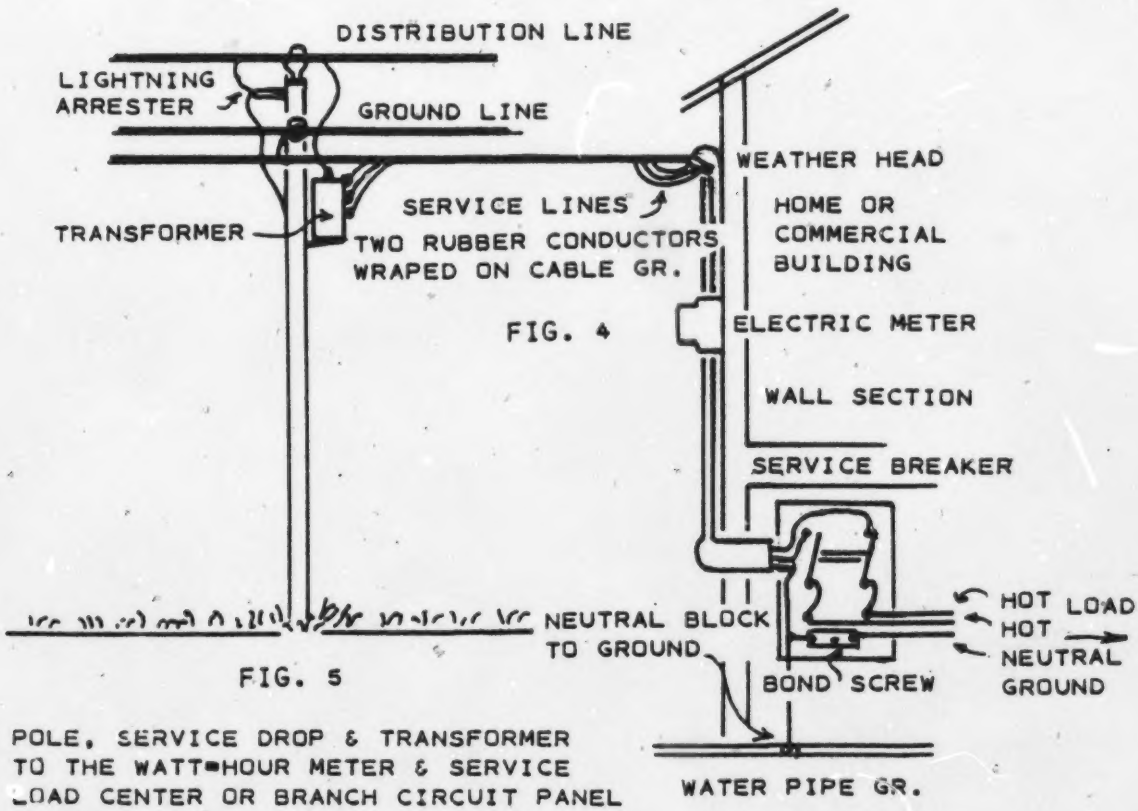


FIG. 4

FIG. 5

POLE, SERVICE DROP & TRANSFORMER TO THE WATT-HOUR METER & SERVICE LOAD CENTER OR BRANCH CIRCUIT PANEL

The power company usually provides the three-wire service drop to the home--through the weather head to the meter base. The power provided is usually from a center-tapped single-phase transformer. Circuit construction for the home owner begins at the meter base. (The weather head he also provides.) Branch circuit construction begins in the breaker panel. Fig. 5, 4, 5 (cont.) and Fig. 7. Simulation exercises with the magnetic block units begins with the breaker panel. Fig. 5 (cont.) The simulator's power is supplied by a set of D cells and represents an instantaneous peak AC polarity value (equal to peak 1/2 cycle AC) as shown by the positive and negative signs assigned to the transformer and to the cells. When the buss lines are to be energized in the breaker panel, the contacts in the main breaker are to be bridged with hook-up wire. (A commutation switch, four-way switch, may be placed between the cell leads and breaker mains to simulate alternating current (alternating DC)--but will allow low voltage filament lamps or back to back red-green LEDS to operate and simulate 220 volt single-phase circuits while simulated 110 volt circuit LEDS operate only on half instantaneous cycle. (In real domestic branch circuits, current flows during both 1/2 cycles on both halves of the transformer secondary.) Each buss line, which is an extension of an outside transformer leg, connects to every other vertical circuit tap. This arrangement presents (in real application 110 volts between each tap and the transformer center tap or neutral; 220 volts (simulated) exists across the two outside legs, neutral is ground and is not in the circuit; however, a green colored conductor or ground is attached to the chassis of the appliance). With the simulator the student may select 1.5, 3, or 4.5 VDC depending on the LEDS selected and used. 220 VAC circuit simulation would be double the 110 VAC simulation voltages just mentioned and the back to back LED would also require a series dropping resistor. Visual luminence differences on the LEDS may or

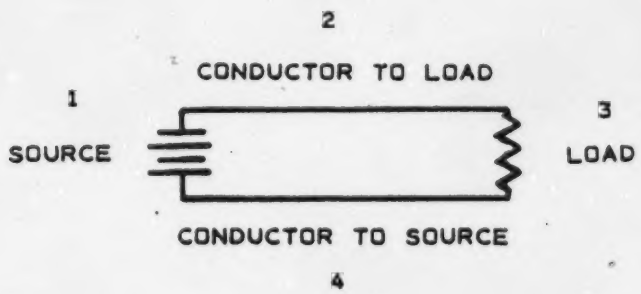
may not be noticeable. The buss bars deliver power to both sides of the branch circuit panel and all taps are overload protected by (jumper) fuses. (Jumpers simulate fuses in this case, but do not open the circuit to protect against real shorts or overloads. This could be effected by using certain diodes.) The center-tap of the transformer or battery pack is connected to the neutral block and is grounded. THE NEUTRAL BLOCK IS NEVER FUSED, NOR IS THE NEUTRAL BROKEN OR MADE CAPABLE OF BEING BROKEN THROUGHOUT THE ENTIRE BRANCH SYSTEM! (TO REPEAT: to disconnect a neutral wire from a live circuit places the technician in grave danger as the loads up-stream place him in series with ground. This act allows all the current drawn by up-stream paralled appliances to go to ground through him.) When power is taken from the breaker panel or branch circuit panel buss bars, it is then fused which places an upper limit on the amount of current which may be drawn from each branch circuit. The fuse is always in the outside transformer leg of the branch circuit. To simulate 220 volt branch circuit protection, both legs are fused. The neutral is not in the circuit, but is attached to the appliance chassis as ground. THIS 220V GROUND CONDUCTOR IS ALWAYS GREEN AND IS NEVER USED FOR ANY OTHER PURPOSE!

Using the cell-powered simulator, the instantaneous value of the service lines and buss bars provides polarized current to the branch circuits. 110 volt simulated branch circuits should always be constructed viewing the outside leg as being Pos. + in charge, with the anode of the LED attached to the brass or gold terminal of the lampholder or outlet. Hot leads, then, attached to hot terminals or switch legs when operational are Pos. + in charge and cause forward bias and conductance--glowing LEDS. When the LEDS are placed in the circuits observing correct polarity, only one service leg will "work." To effect an easy instantaneous change in polarity the student may put a commutation switch (4-way switch) in the service lines between the

battery pack and the main breaker. This reverses the polarity without disconnecting and reversing the supply source of power. This also works for 220 VAC simulation using a back to back LED. In effect, the service polarity is reversed just as a transormer reverses polarity during a 1/2 cycle change. Understanding the polarization of AC circuits is extremely important; it is the key to understanding grounding principles and current isolation techniques. Discuss polarization often with your instructor and others until it is understood.

The question at this point remains, "How does the student learn to construct, control, and color code interior wiring circuits through simulation exercises?"

First, a few basic requirements of electrical circuits should be explored, constructed, and understood. It follows then the student should know what the minimal requirements for constructing an electrical circuit are. They are: (1) a source of EMF (electromotive force--a cell, battery, or generator), (2) a conductor to deliver the current to the load resistor, (3) a load resistor or appliance, (4) a conductor to return current from the load resistor to the source. Fig. 6.



FOUR ESSENTIALS OF A CIRCUIT

FIG. 6

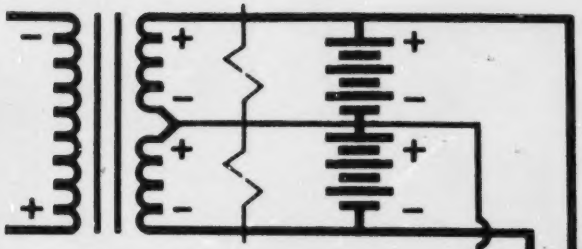
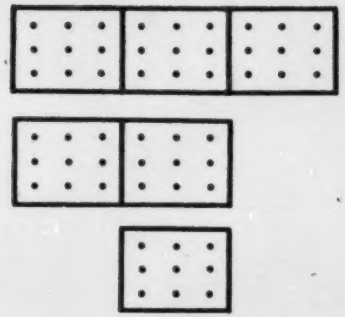


FIG.(5 CONT.)



GANGED BASES TO PROVIDE SWITCH & RECEPTICLE CONTACTS IN REDUCED SPACE.

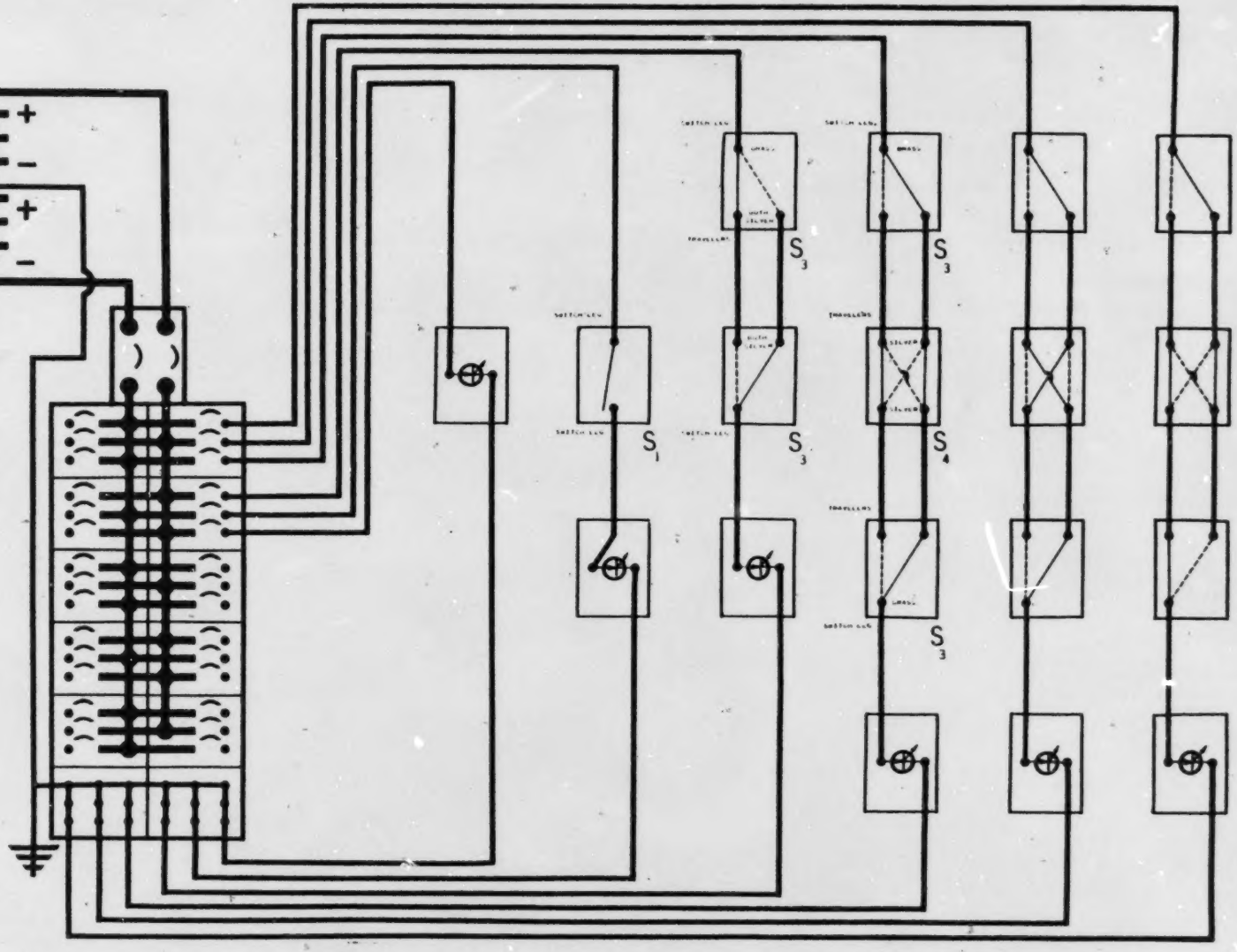


FIG. 7

FIG. 8

In the following circuits, Fig. 7, control switches are placed to facilitate the "on" or "off" mode of the circuit. Switches are always placed in the "hot" side of a circuit, that is, between the breaker and the appliance. (Remember, this is the outside leg portion of the transformer.) This removes the appliance from the circuit when the switch is opened and does not break the neutral. (Remember, breaking the neutral is an infraction of the rules.)

With the information available and looking at Fig. 7, place magnetic units to represent the branch circuit panel and the first unswitched circuit. Wiring exercises may begin here, just follow the directions which follow along with Figs. 7, 8, 9, 10. Note here that when drawing a schematic from which to construct a circuit, always draw the neutral (white) or return conductor first and denote it as white. Drawing the white or neutral on the schematic first removes some of the mystery from the drawing and subsequent color coding of the circuit. The need and reason for this coding becomes more obvious as the circuits get complex. NOTE HERE ALSO, THE GROUND WIRE SYSTEM (BARE WIRE) PARALLELS THE NEUTRAL WIRE AND PROVIDES AN AUXILIARY PATH TO GROUND SHOULD THE NEUTRAL FAIL OR CEASE TO FUNCTION PROPERLY FOR SOME REASON--BROKEN WIRE. (The ground wire is not illustrated in the drawings. To include the ground wire tends to clutter and confuse the drawing and the student.) (Ground is bare wire in 110 volt system, in 220 volt system the ground is a green insulated conductor!)

In the second branch circuit, Fig. 7, a single-pole switch S-1, has been placed in the "hot" side of the line between the fuse and the appliance. It, too, had the neutral drawn in first. Notice that a black wire is used to service the load in the first circuit. This is also true of the second circuit. Black, then, is used to denote the "hot," or switched lead or side of the line (switch-leg); however, other colors may also be used as well (and sometimes

white if it is identified). You will learn these differences with practice.

The next circuit, Fig. 7, uses two three-way switches S-3. Make note the neutral or white conductor which returns current from the appliance to the neutral block was drawn in first. The "hot," or switched side of the line, is interrupted by two three-way switches placed between the breaker and the appliance. The hot line approaching the series ganged three-way switches is called a switch-leg. The two conductors running between the two switches are known as travelers, the conductor leaving the second switch and connected to the appliance is also known as a switch-leg. (Notice the schematic is so labeled.) The final three circuits use two three-way switches S-3, with a four-way switch S-4 sandwiched between. Another variation is to sandwich a second four-way S-4 between two three-ways S-3. This allows switching from four positions. By sandwiching four-way switches between three-way switches, switching may take place from an infinite number of places. The conductor leaving the three-way switch and attached to the appliance, again, is called the "switch-leg." Switch-leg terminals on three-way switches are designated by using an odd color terminal (brass or gold) while the traveler terminals (a pair) are usually silver in color.

In summary, there are single-pole S-1, three-way S-3, and four-way S-4 switches in common use in interior wiring. Each has an internal switching configuration, Fig. 8.

The single-pole S-1 is either open or closed. The three-way switch S-3 is an either/or switch. It is either in one position/or the other. The same is true of the four-way switch S-4. When three-way and four-way switches are ganged together in series to form "switch trains" practical switching from more than one position begins to happen. You will notice that to switch a circuit from--:

(1) one position--use one single-pole switch S-1
(2) two positions--use two three-way switches S-3
(3) three positions--use two three-way switches S-3, and one four-way S-4 sandwiched
(4) infinite # of positions--sandwich four-way switches S-4 between three-way switches S-3

Learn to recognize these switching configurations and arrangements; they are the key elements to most domestic lighting circuit controls. Motors being inductive circuit machines usually require more sophisticated controls. Special texts on motor controls are available.

When doing the actual layout and drawing of schematics, the simplicity of arrangement of switched circuits sometimes grows complex and obscure. Do not allow this maze to frighten you. Look at the routing, color coding and switching situation examples in Fig. 9 and 10. After you have studied these, other such problems will be simpler to solve.

The simulation system uses single conductor #28 or #30 gauge wire. Green is always used as the ground. White is neutral, and black, red, and white are used as switched conductors. It is important to understand at this time that: NEUTRAL IS ALWAYS WHITE, but WHITE ISN'T ALWAYS NEUTRAL. The student will learn to recognize this seemingly deceptive statement as the practice of color coding and the identity of switched leads progresses. (Refer to Fig. 9 and 10.) Remember, NEUTRAL IS ALWAYS WHITE, it is drawn in first in a schematic and designated as a white conductor. When making up circuits, the job is simplified if all the neutral whites are identified and attached, spliced, or wrapped to their designated anchor or terminals--observing polarity carefully. Observing these simple statements makes drawing schematics easier, wiring and color coding simpler to understand, and is the basis of good electrical practices. The student is reminded again, the neutral nor the ground conductors are to be broken by any device, switch, etc.

PRACTICAL SWITCHING ARRANGEMENTS

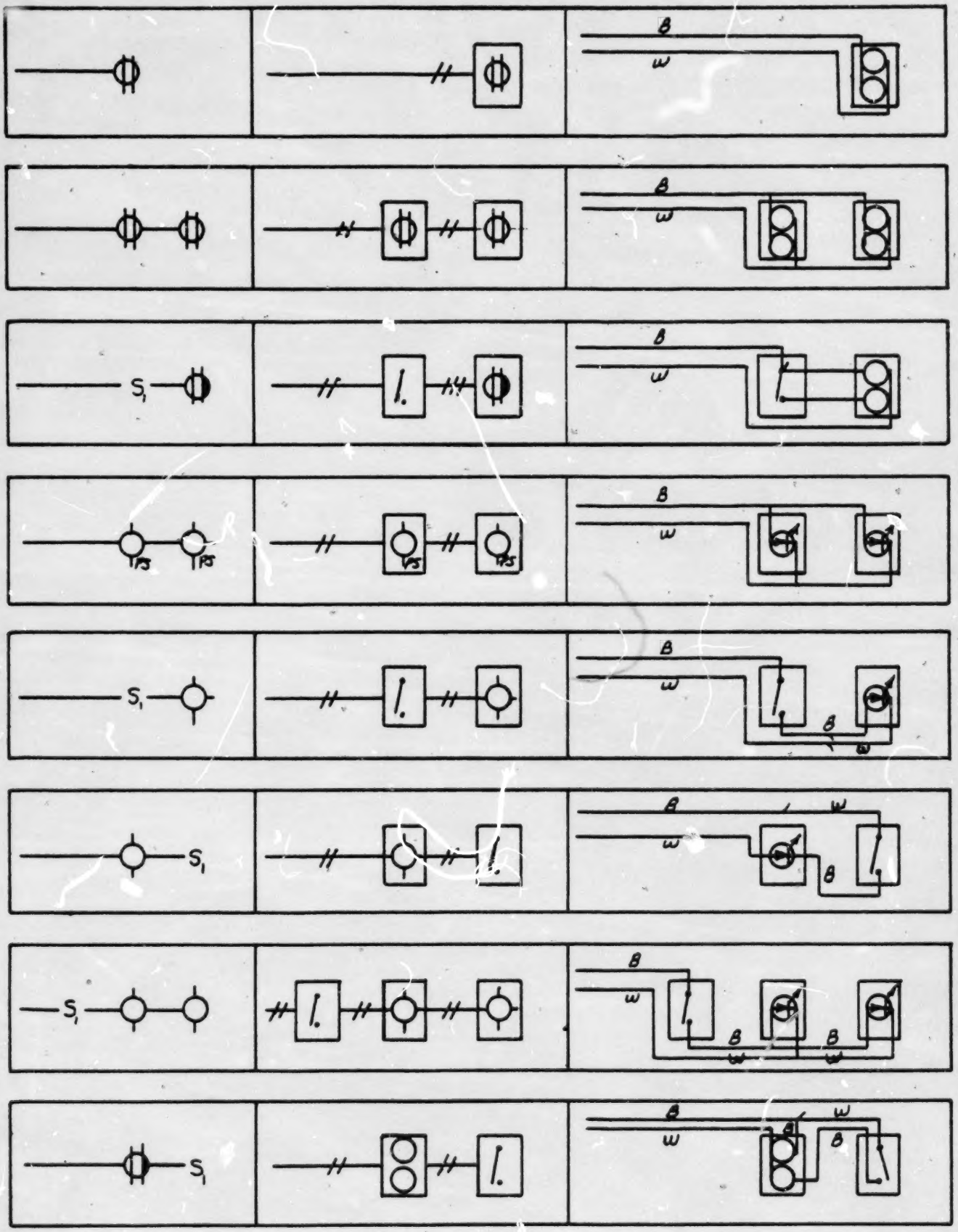


FIG. 9

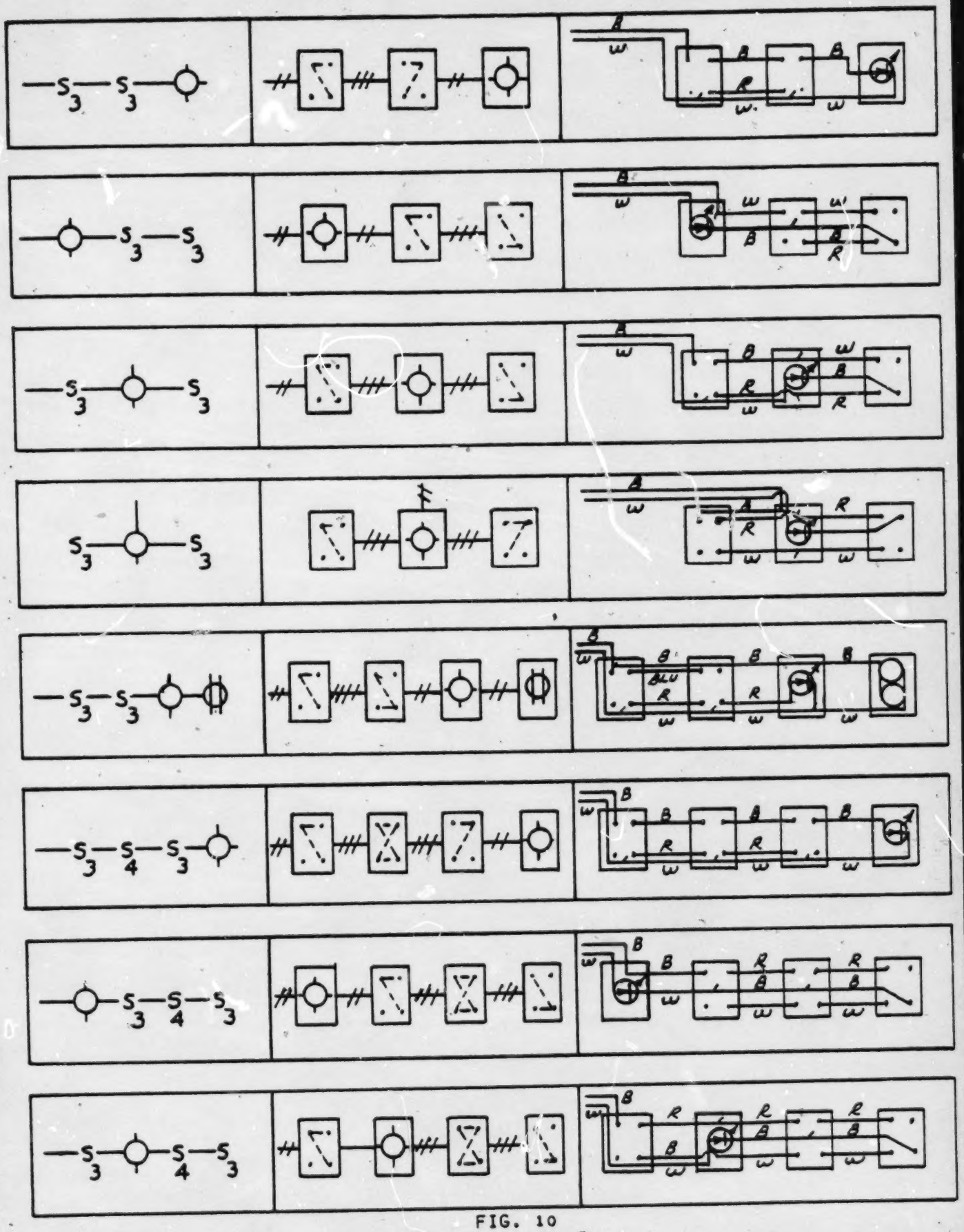


FIG. 10

Remember and practice no power attached to any circuit while under construction or repair, even through the simulator presents no hazard. If the domestic counterpart (110 or 220 VAC) was at hand your safety would be in danger. Locking off the power source is the only real safe way to deal with the problem. That stops others from engaging the power and jeopardizing your safety. It may also save you from your own negligence or errors.

Now that some switching exercises have been reviewed, progress may be made toward the installation of circuits on an architectural floor plan.

The initial step taken when planning the installation of electrical service to a home is to assess the user's needs. A needs assessment of this type is usually started with a floor plan of the home. Fig. 11. (This may be any floor plan.) If there is a basement or second floor, this too must be assessed. If the home is to be custom built, the buyer should be consulted about the family's needs. Questions should be especially directed to special needs. Fig. 12. Care must first be taken relative to proximity of the service entrance to the power source. That usually determines the placement of the breaker panel or at least some compromise effort. The breaker panel is usually close to the heavy use area, namely the kitchen, since most heavy power uses in the home are in this area, but not always. The reason for this placement is to initially reduce the cost of large cables used to service electric stoves, laundry equipment, dryer and electric water heater, and the air conditioner, and to reduce $P=I^2R$ losses. Lighting and general use circuits customarily do not require much current and as a result long runs with small diameter conductors may be used, AWG (American Wire Gauge) #12 or #14. The technician should proceed from one room to the other questioning his patron about the placement of convenience outlets, switches, switched wall outlets, switched overhead

light fixtures, kitchen conveniences, heating plant requirements, laundry requirements, bathroom needs, basement needs, workshop, garage, outdoor use areas, and the placement of telephone jacks (the telephone company does this as a prewire job). All these questions, Fig. 12, along with their answers, the Order Sheet Fig. 13, must be recorded and spotted on the floor plan, Fig. 11 and 14, as an electrical symbol, Fig. 15. Any special notes or requirements, including switches and control devices must appear also. Single dash lines are sometimes drawn to indicate to the technician which fixtures are controlled from which switch or group of switches, Fig. 14. A good technician can take this floor plan, Fig. 11, and figure his bill of materials, Fig. 16, to complete the job. This includes determining the load or watts consumed by the circuit, Fig. 17. (Load parameters are approximate.) You the student, will use the floor plan to arrange all your simulation exercises.

The simulation exercises may be based on any floor plan. The floor plan that appears in Fig. 11 is perfect since a set of circuit and switching directions are included. Where the electrical symbols appear on this floor plan, place magnetic base units with their appropriate wire-wrap pins. At this point, it is beneficial to verbalize and write down your own orders (as the patron gave them to you--provides excellent practice if helped by a friend), for it becomes apparent that directions are needed to know what to do. This is a good practice exercise because it sharpens the technician's planning ability. As with any electrical or electronic circuit plans, the fixture, switch, anchors, and component locations are determined first. (This was done by placing the symbols on the floor plan appropriately.) In this case that includes the breaker panel. With the set of requests the customer gave, and the orders we have written ourselves about the circuits and their control devices, the work of actual wiring may begin.

The breaker panel may be placed as shown using several magnetic bases, pins intact. Notice that one pin base (4-way switch) is used as a main breaker. The other pin bases are placed as shown. (The crescent line indicates a fuse or breaker, a thin piece of wire will bridge this gap to simulate it.) Notice the branch circuits on each side come off the LEFT then the RIGHT buss line. (Black dot indicates physical and electrical connections.) That effectively places each fused branch circuit on opposite halves of the transformer relative to ground. (Keep this fact in mind when attempting to balance the load on the transformer.) This arrangement is also more suitable when constructing 220 volt circuits, as the breaker (a double-pole single throw switch) may be one composite unit supplied by the transformer secondary taken from any two adjacent buss pins or studs.

In addition to the fused studs and pins, it is necessary to have a neutral block, isolated and insulated from the buss lines and studs. The neutral block is, however, grounded along with the fuse box (breaker panel) unless the system is to float above ground. In practice, a breaker box or fuse panel has a screw to bond the neutral to the box and the box is grounded to the street side of the water meter or other suitable ground.

It is now time to construct the first circuit. Place Fig. 11 and 14, the large floor plan, over the unfolded hinged metal sheets and fold the edges back--then proceed to place magnetic units over the circuit symbols. With a reasonable portion of the breaker panel pin blocks in place and a neutral block designated (remember, more may be added as needed) and the service drop in position to be connected to the main breaker, no power applied, work may begin on the first branch circuit. Place the Order Sheet, Fig. 13, in front of you and follow each step carefully. Wire in the neutral (white) first. Attach a black lead to a fused pin and route it to a junction box, duplex outlet, lampholder,

or switch, whatever is called for. In practice, the neutral and hot wire (a white and a black conductor) are in a sheathed cable along with a bare ground, usually 12-2/WG. (Cables with a greater number of conductors are also used.) The cable is routed to the point of use, or junction box, while the switching loops travel out to the switch(es) and back to complete the circuit. This reduces the number of wires required in a cable and the size of conductors used in the switching loops, usually #14-2/WG. If difficulty is encountered in determining how to switch various circuit arrangements, refer to Fig. 4, 7, 8, 9, 10. Study these examples until the logic of their arrangement begins to make sense. Apply these examples to your own situations as you progress from one circuit to the next. YOU ARE ON YOUR OWN! GOOD LUCK!

Electricity in its simplest terms is a stream or "current" of electrons which have been set in motion by a magnetic force. Current flow is usually brought about in metal substances since the electrons in their atomic structure are the easiest to set in motion. Porcelains, glasses, rubber, and plastics are known as good insulators (dielectrics) because the electrons in their atoms resist movement and displacement in the presence of a strong magnetic field. (Defined by the terms electromotive force, EMF, or more specifically, voltage E). This pressure, or voltage (E), when coupled with intensity (I) or rate of flow of electrons past a given point in one second (6.24×10^{18}). The intensity of current flow or the ability to do work may be reconverted magnetically into mechanical motion (in a motor), heat (resistive coils), light, and even chemical storage of electrons (in a battery). In the process of changing one form of energy to electricity and back again there are radiation and wire losses. Wire losses may be equated to the phenomenon called resistance (R) or the opposition to current flow. This is exhibited in all conductors and non-conductors of electricity. Non-conductors oppose the displacement of electrons more than conductors. A material is a good conductor when it exhibits little opposition to the flow of current or electrons.

The establishment of a circuit assumes there is: (1) an EMF available, source, (2) a conductor from the source to the load, (3) a load resistor, and (4) a conductor from the load resistor back to the source. These four elements enable the electrical circuit to exist. By convention, the electrical source has been given a sign or designation of polarity to enable the observer to note the direction and flow of unit charge in the circuit and the resultant net loss of charge by passing through a change either wholly or partially in which the charge passes from Pos.+ to Neg.- or a net loss of charge (0). That loss is restored by

passing through the source EMF, in which case the charge is restored by passing from Neg.- to Pos.+. The positive state then represents a unit charge or the ability to do work (to exert a force, voltage). The above represents the classic "current theory" of electricity as opposed to the "electron theory," which is effectively the opposite. The "current theory" of electricity is used in most engineering texts, but not all. Circuit Analysis by Robert Boylestad uses current theory; the two-part text, Electrical Circuits, Direct Current and Alternating Current by Richard Johnson uses electron theory as does the Bell Telephone System for whom the texts were primarily written. The text, Electrical Wiring Design and Construction, by Robert C. Johnson, again uses current theory of electricity. They are all fine texts, but the student must realize the basic difference in theory used or he will not understand them.

A series circuit is the simplest electrical circuit. It is easily identified since each resistor is connected to the next so there is only one path for the current and as a result the current in the circuit is determined by the total resistance R_t.

The total resistance of a series circuit is found by simply adding the individual resistors. By knowing the source voltage and the total resistance of a series circuit, the composite current may be determined through the use of Ohm's Law. (This same current flows through each successive resistor.) $I_t=\frac{E_t}{R_t}$, I_t being the composite current the value sought, E_t being the EMF or voltage value, and R_t or total resistance. In addition, the source voltage is equal to the sum of the voltage drops through the individual resistors. According to Kirchoff's Voltage Law (KVL) the net voltage in a series circuit is always equal to 0. That is, when two or more series resistors are present in a circuit, the voltage will drop in a direct relationship with each resistive value, but the resultant drops when totaled will be equal to the source voltage or 0 volts if the net charge of the source and the net voltage losses through each resistor are added algebraically. The voltage drop across each resistor again may be determined using Ohm's Law, E=IR. By adding the instantaneous voltage drops (V), (that is voltage taking on a negative value by passing through a resistor Pos.+ to Neg.-), this sum will equal the source voltage as when the current re-enters the source and the net charge goes from Neg.- to Pos.+ or $Eout=v_1+v_2+v_3$ drops.

Given: Three load resistors (LEDS) 50Ω, 50Ω, 50Ω connected in series to a 3 VDC source. (The LEDS are designed to conduct .020 amps current, for effective brightness.) 50Ω resistors in series are dealt with as composite units of

resistance. The resistors are used as current limiters, with LEDS, so the LEDS are not damaged when they begin to conduct as their resistance drops to 0 and current is limited by the internal resistance of the source only. Heat is usually generated which destroys the light emitting junction. If the number of LEDS in a series circuit is reduced, the series resistor would be changed so the current would not exceed .020 amps (although R_t would be same if E was constant).

Solution: Remember, there are several ways to solve series circuit problems. Always search for two knowns and the third may be found by applying Ohm's and Kirchoff's Laws. By all means study problems in other fine texts from the appendix, the variety of problems are endless.

(A) As stated previously, the current in a series circuit is determined by the total resistance:

$R_t=R_1+R_2+R_3=$ 50Ω 50Ω 50Ω =150Ω

$$I_t=\frac{E_t}{R_t}=\frac{3V}{150}$$

(B) The current is the same throughout the circuit.

$I_t=I_1=I_2=I_3=$ .020 amps

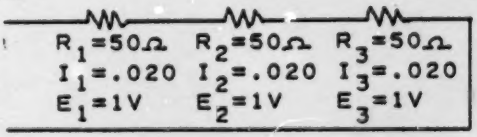
.020A=.020A=.020A=.020A=.020A

(C) Ohm's Law determines individual voltage drops through the load resistor.

$V_1=I_1R_1=.020x50=1.000$ V

$V=I_2R_2=.020x50=1.000$ V

$V=I_3R_3=.020x50=1.000$ V



(D) Source voltage (EMF) is equal to algebraic sum of individual voltage drops.

$E=V_1+V_2+V_3$

3 EVDC=1v+1v+1v=3VDC

(E) The power consumed by each resistor P=IxV

$P_1=I_1xV_1=.020x1V=.020W$

$P_2=I_2xV_2=.020x1V=.020W$

$P_3=I_3xV_3=.020x1V=.020W$

Total power consumed .060W

The most important circuit in interior wiring is the parallel circuit. This circuit is easily identified since it provides the current with an equal number of alternate paths as there are load resistors. (The current may pass through any load resistor without passing through another resistor, in other words, the current splits.) The sum of the branch currents equals the value of the source current. $I_t-(I_1+I_2+I_3 \text{etc.})=0$. Logically this states the voltage is the same through each load resistor and is equal to the source voltage. $E_1=E_2=E_3=E$ source. It follows then the total current is the sum of the individual branches.

$$I_1=\frac{E_1}{R_1}=$$

$$I_2=\frac{E_2}{R_2}=$$

$$I_3=\frac{E_3}{R_3}=$$

I_t=Total Current=$I_1+I_2+I_3$

Through such a process using the individual load resistors the branch currents are found. To find the joint resistance of a parallel circuit the following formula is used:

$$R_t=\frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}} \text{ etc.}$$

It is found that the total or joint resistance of a parallel circuit is less than the smallest individual resistor value. Kirchoff's Voltage Law (KVL) states the algebraic sum of E voltage rises and voltage drops in a closed loop is zero--or

$E-(V_1+V_2+V_3 \text{ etc.})=0$

3 EVDC$-(V_1+V_2+V_3)=0$

3 EVDC-3 VDC=0

Given:

E_t=3VDC

R_1=150Ω

R_2=150Ω

R_3=150Ω

I_1=.020A

I_2=.020A

I_3=.020A

V_1=3VDC

V_2=3VDC

V_3=3VDC

I_t=.060

R_1=150Ω	R_2=150Ω	R_3=150Ω
I_1=.020A	I_2=.020A	I_3=.020A
V_1=3VDC	V_2=3VDC	V_3=3VDC

I_t=-(I_1+I_2+I_3 etc.)=0

I_t=-(.020A+.020A+.020A)=0

therefore: .060A out=.060A drop=0

Through Ohm's Law it also becomes apparent that: the voltage in a parallel circuit is everywhere the same.

Solution:

V_1=I_1xR_1=.020Ax150=3VDC

V_2=I_2xR_2=.020Ax150=3VDC

V_3=I_3xR_3=.020Ax150=3VDC

The student is also directed to note the current flow is inversely proportional to resistance and directly related to the source voltage. This logically leads to the adoption and use of the power equations which are a more practical means of analyzing complex circuits as opposed to determining their joint resistance or other means of circuit analysis. In short, to use other means than the power equations is just to time consuming.

Power is defined as the rate of doing work and its unit is the watt.

P=IxV

In the above circuit then:

P_1=I_1xV_1=.020x3V=.060W

P_2=I_2xV_2=.020x3V=.060W

P_3=I_3xV_3=.020x3V=.060W

Total power consumed=.180W

The total power in any circuit may be arrived at by multiplying the total current by the impressed voltage, likewise the power dissipated through an individual resistor may be determined by using the I and V values of that resistor. The power yielded is in watts or kilowatts. Since this is an instantaneous value, power companies through the use of a voltammeter (watt-hour meter) determine the power consumed for billing and is given in KWH or kilowatt hours.

$P=\frac{w}{t}$ or $w=pt$ or total cost$=\frac{pct}{1000}$

(746 watts constitutes one horse-power)

Two other power formulas are:

$P=\frac{E^2}{R}$ and $P=I^2R$

RECOMMENDED READING FOR JUVENILES

Shields, John Pottrer, Novel Experiments with Electricity, Howard W. Sams & Co., Inc., The Bobbs-Merrill Co., Inc., Indianapolis, Indiana, 1970.

Bender, Alfred, Science Projects with Electrons and Computers, Arco Publishing Co., Inc., 219 Park Avenue South, New York, New York 10003, 1977.

Graf, Rudolf F., Safe and Simple Electrical Experiments, Dover Publications, Inc., New York.

Rayer, F.G., The Pegasus Book of Electrical Experiments, Dobson Books Ltd., 80 Kensington Church Street, London, W.8 Great Britain, 1968.

Rayer, F.G., The Pegasus Book of Electronic Experiments, Dobson Books Ltd., 80 Kensington Church Street, London, W.8 Great Britain, 1971.

Richter, H.P., Wiring Simplified, Park Publishing, Inc., P.O. Box 5527 (Lake Street Station), Minneapolis, Minnesota 55408.

Richter, H.P., Practical Electrical Wiring, Residential, Farm, Industrial, Tenth Edition, McGraw-Hill Book Co., New York, 1976.

RECOMMENDED READING FOR YOUTH AND ADULTS

Boylestad, Robert L., Introductory Circuit Analysis, 3rd Ed., 1977, Merrill Publishing Co., 1977.

Johnson, Robert C., Electrical Wiring: Design and Construction, Prentice Hall Series in Electronic Technology, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Johnson, J. Richard, Electrical Circuits, (two parts) Part 1, Direct Current, Part 2, Alternating Current (Theory and Analysis), Holt, Rinehart and Winston, Inc., 1970.

DeFrance, J.J., Electrical Fundamentals, Prentice-Hall, Englewood Cliffs, New Jersey, 1969.

Shrader, Robert L., Electrical Fundamentals for Technicians, McGraw-Hill Book Co., New York, 1969.

There are many fine texts on the subject of electricity and electrical wiring. A complete list and prices may be obtained by requesting such from Technical Instruction Systems, P.O. Box 4402, Springfield, Illinois 62708.

FIG. 12
Questions for Patrons, Assessing Needs

Here are some suggested questions a technician should ask a patron who is in the process of planning the electrical service in a new home.

Where will the service lines enter the home?

What size (amp.) service panel does the customer desire? They may need help here, be prepared to give them suggestions and assistance.

Where do they wish the service panel located? This may require a compromise effort depending on several factors.

Where will the major appliances be located? Care must be taken to locate appliances operated on 220 volt branch circuits, air conditioner(s), clothes dryer, etc.

What are the requirements and desires for existing out-buildings or for those planned for future construction?

What needs exist for other outdoor installations, lighting, heating, appliance outlets?

The technician must also proceed from one room to the other questioning his patron about the placement of convenience outlets, switches, switched wall outlets, switched overhead light fixtures, kitchen conveniences, heating plant requirements, electric heat, electric heat boosters, auxiliary blowers in a forced air system, laundry requirements (may be more than one), bathroom needs, basement needs, workshop garage, telephone jacks (call telephone service for pre-wire on new home).

All these questions, along with their answers (Order Sheet Fig. 13) must be recorded and spotted on a floor plan (as Fig. 11 and 14) as an electrical symbol (Fig. 15). Any special notes or requirements, including switches and control devices must appear also.

This list may be continued--develop questions of your own and attempt to be ingenious and inventive in the use of lighting effects and your skills with electricity, your customers will appreciate your interest in solving their problems.

FIG. 13
Order Sheet
(What is to be done as the result of needs assessment?)
(Based on Fig. 11 and 14)

Circuit #

1. Bedroom and closets, one outlet switched S-1, overhead light switch S-1, outlets all 110 V, closet lights on pull chains.
2. Bedroom and one bath, bedroom one outlet switched S-1, overhead light switched S-1, outlets all 110 V; bath vanity lights S-1, medicine cabinet and overhead lights S-1 with medicine cabinet switches overriding S-1. NO outlets close to tub area (a safety hazard that encourages use of appliances around water, well grounded at that).
3. Master bedroom and bath, bedroom one outlet switched S-1, overhead light switched, two positions, S-3, all outlets 110 V; bath overhead switched S-1, power on medicine cabinet and one outlet. Rear hall lights four positions switched.
4. Front hall lights and refrigerator, front hall lights switched three positions.
5. Front light and front outside. Switch according to patron's choice.
6. Kitchen and family room lights, fireplace lights switched two positions. Overhead lights patron's choice of lighting and switch arrangement.
7. Kitchen outlets.
8. Garbage disposal circuit.
9. Dishwasher circuit.
10. Living room outlets and lights, switched outlet two positions, fireplace lights S-1, all outlets 110 V.
11. Washer and dryer circuit (110 V only).
12. Garage outlets and lights, garage switched four positions, all outlets 110 V.
13. Rear outside outlets and lights switched, patron's choice.
14. Furnace
15. Basement workshop circuit, patron's choice.
16. All other basement outlets and lights.
17. & 19. Electric clothes dryer, 220 V only.
18. & 20. Electric Range

21. & 23. Electric water heater

22. & 24. Air conditioner

25. & 27. 60 amp. feed to breaker in outbuilding

26., 28., 29., 30. Circuits remain for assignment

SYMBOLS
ELECTRICAL WIRING

ADDITIONAL SYMBOLS MAY BE FOUND BY REFERING TO THE AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) SEE BELOW

	BATTERY
	GROUND GR.
	POWER PANEL
	2-WIRE CABLE
	3-WIRE CABLE
	4-WIRE CABLE
----	SWITCH LEG INDICATION
-----	WIRING EXPOSED
———	WIRING CONCEALED
— — —	WIRING CONCEALED IN FLOOR
S_1 OR S	SINGLE POLE SWITCH
S_2	DOUBLE-POLE SWITCH
S_3	3-WAY SWITCH
S_4	4-WAY SWITCH
S_{WP}	WEATHERPROOF SWITCH
S_P	SWITCH W/PILOT
$_{DW}$	SPECIAL PURPOSE OUTLET SUBSCRIPT INDICATES USE DW-DISHWASHER, ETC.
X"	MULTI-OUTLET ASSEMBLY X LIMITS IN INCHES
$_S$	SWITCH AND SINGLE RECEPTACLE
$_S$	SWITCH AND DOUBLE RECEPTACLE
$_R$	RANGE OUTLET (220)
	DUPLEX OUTLET
$_{GR.}$	DUPLEX OUTLET W/GROUND
	DUPLEX OUTLET SPLIT CIRCUIT
$_{GR.}$	SPLIT DUPLEX OUTLET W/GR.
$_{WP}$	WEATHERPROOF OUTLET
J	JUNCTION BOX
	LIGHTING PANEL
	CEILING OUTLET
	WALL BRACKET
	FLOOR OUTLET
	CEILING OUTLET RECESSED FIXTURE
S_T	TIME SWITCH
S_D	DOOR SWITCH
$_{PS}$	LAMPHOLDER W/ PULL SWITCH
	FLUORSCENT FIXTURE
	ANNUNCIATOR
	OUTSIDE TELEPHONE
	INTERCOM TELEPHONE
	BUZZER
	CHIME
	BELL
	PUSHBUTTON
	HEATING UNIT
M	MOTOR
TV	TV OUTLET

SYMBOLS USED TO DESIGNATE ELECTRIC OUTLETS ON ARCHITECTURAL FLOOR PLANS. ALL SYMBOLS ARE TAKEN FROM AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) STANDARD Y-32.9-1972.

FIG. 15

FIG. 16
Bill of Materials

A Bill of Materials is a list of articles the electrician will need to complete the installation of a complete service and branch circuit electrical system as specified by his customer. The list customarily commences with the service head, service lines, ground rod, ditching and backfill expenses, heavy-wall conduit, meter base and the cost estimate on the entire job as specified on the contract--completed. In most instances it is practical and advisable for the technician and the buyer to specify the exact size, quality, and mode of installation. For unspecified expenses a written agreement should be reached before work starts so there are no surprises as to whose responsibility costs remain.

Once the branch circuit panel has been decided on and the order sheet specifies everything in the electrical installation, the "sites" (boxes) may be counted and the terminal identified. The number of handy boxes, junction bases, octagon boxes, ganged boxes, hangers, pull-chain lampholders, switches and their types S-1, S-3, S-4 should be tabulated and colors specified. This includes the color of switch cover plates. The number of duplex outlets should be counted and their color noted as well as cover plates. In addition, the number and gauge of sheathed cables should be specified and the amount needed estimated. This includes cables for inside and outside use as well as cables for switching and control purpose, and service cables.

It is also a good idea to specify the styles, colors, and quality of light fixtures that are to be installed. There are many hard feelings that can develop on this issue. First, determine whose responsibility and expense the fixtures are to be. Many customers will have a desire to choose their own fixtures or even exchange a few of them as they are installed. Be prepared to accommodate their needs and desires through the fixture dealer or allow them to provide their own fixtures, but you must make the procedure clear before the job commences.

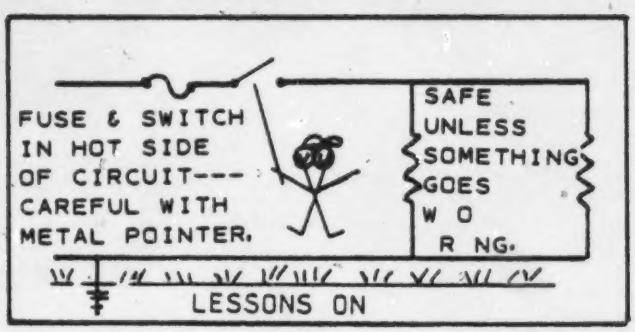
Once the bill of materials has been created, the order for materials may be effected and brought to the building site. These materials should be accounted for before work commences, they should never leave the site or be tampered with--be tight--some persons will sue if they believe they are being "fudged on."

FIG. 17
Appliance consumption ratings in watts

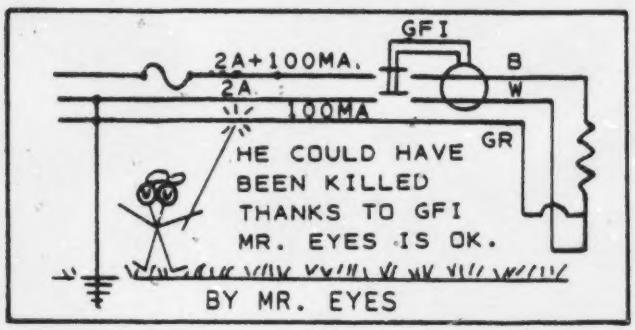
Here is a list of common 110 volt appliances and the amount of power in watts each draws or consumes:

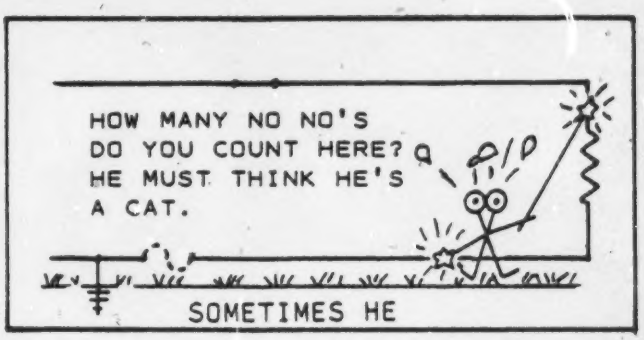
Incandescent lamp	5 watts and up
Fluorescent lamp	10 watts and up
Sun lamp (ultraviolet)	300 watts and up
Heat lamp (infrared)	250 watts and up
Hot pad	50 watts and up
Electric blanket	100 watts and up
Space heater	800 watts and up
Air conditioner	800 to 6000 watts
Iron	500 to 1500 watts
Electric stove	5000 to 15000 watts
Toaster	500 to 1200 watts
Coffee pot	500 to 1000 watts
Electric skillet	1000 to 1200 watts
Electric roaster	1000 to 1500 watts
Vacuum cleaner	600 watts
Refrigerator	300 to 600 watts
Freezer	300 to 600 watts
Mixer	150 to 300 watts
Dishwasher	1000 to 1600 watts
Garbage disposal	600 to 1000 watts
Water heater	2500 to 6000 watts
Clothes dryer	5000 to 10000 watts
Small appliances	50 to 500 watts
Furnace motor	1200 watts and up
Power tools	600 to 1400 watts

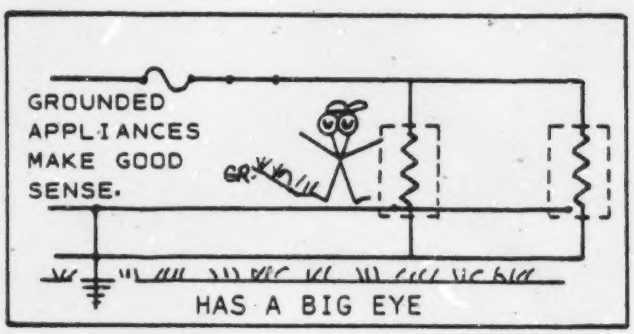
The power consumed by an appliance can differ widely depending on the manufacture and its intended use. Some appliances are designed for light and intermittent duty and some are designed for heavy and continuous duty. To be certain of all consumption rates for appliances to be installed or in use, check the name plate for the number of watts the appliance consumes. If the power consumption information is not readily available, the sales person or manufacturer's representative will be happy to provide such information from the technical information which they have.


FUSE & SWITCH IN HOT SIDE OF CIRCUIT--- CAREFUL WITH METAL POINTER.
SAFE UNLESS SOMETHING GOES W O R NG.
LESSONS ON

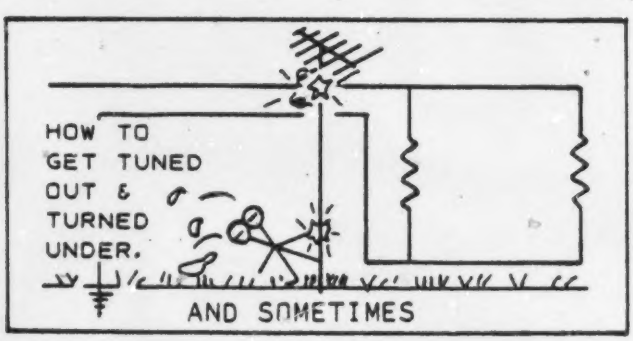
FUSE & SWITCH IN WRONG SIDE OF LINE, SWITCH OPEN--BUT-- MR. EYES W/LOAD, GROUND
IN SERIES CURRENT TO VIA FRIEND.
GROUNDING SAFETY

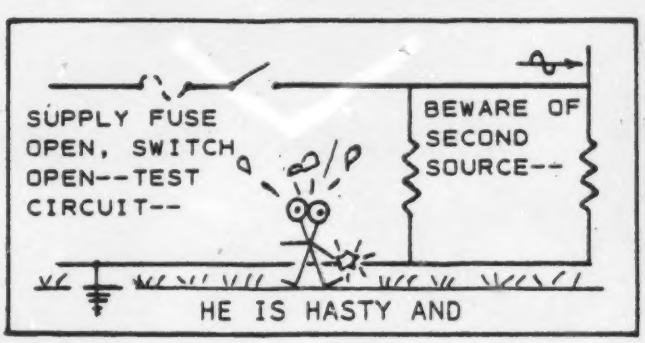

GFI
2A+100MA.
2A
100MA
B
W
GR
HE COULD HAVE BEEN KILLED THANKS TO GFI MR. EYES IS OK.
BY MR. EYES


HOW MANY NO NO'S DO YOU COUNT HERE? HE MUST THINK HE'S A CAT.
SOMETIMES HE

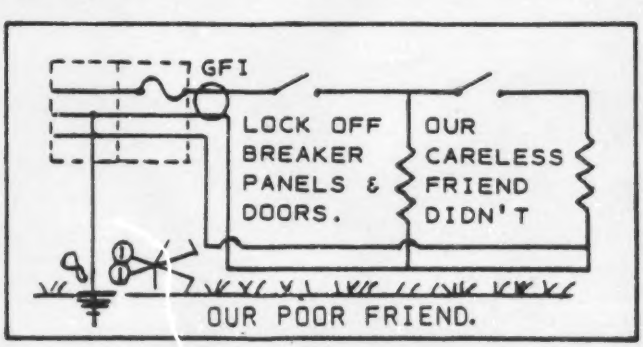

GROUNDED APPLIANCES MAKE GOOD SENSE.
GR
HAS A BIG EYE

TOUCHING TWO APPLIANCES HAZARDOUS, POSSIBLE POTENTIAL DIFFERENCE.
FOR SAFE PRACTICES


HOW TO GET TUNED OUT & TURNED UNDER.
AND SOMETIMES


SUPPLY FUSE OPEN, SWITCH OPEN--TEST CIRCUIT--
BEWARE OF SECOND SOURCE--
HE IS HASTY AND

WHAT IS OUR FRIEND DOING ON THAT METAL LADDER?
CARELESS---


GFI
LOCK OFF BREAKER PANELS & DOORS.
OUR CARELESS FRIEND DIDN'T
OUR POOR FRIEND.